L-141

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

WARTIME REPORT

ORIGINALLY ISSUED

July 1944 as
Confidential Bulletin L4G17

INVESTIGATION OF EFFECTS OF VARIOUS CAMOUFLAGE PAINTS AND PAINTING PROCEDURES ON THE DRAG CHARACTERISTICS OF AN NACA $65_{(421)}$-420, a = 1.0 AIRFOIL SECTION

By Albert L. Braslow

Langley Memorial Aeronautical Laboratory
Langley Field, Va.

NACA

WASHINGTON

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

CONFIDENTIAL BULLETIN

INVESTIGATION OF EFFECTS OF VARIOUS CAMOUFLAGE PAINTS AND PAINTING PROCEDURES ON THE DRAG CHARACTERISTICS OF AN NACA $65_{(421)}$-420, a = 1.0 AIRFOIL SECTION

By Albert L. Braslow

SUMMARY

The effects of various camouflage paints and painting procedures on the drag characteristics of a 60-inch-chord low-drag airfoil have been investigated in the NACA two-dimensional low-turbulence pressure tunnel. A typical field application of camouflage paint increased the section drag coefficient of the aerodynamically smooth airfoil at a Reynolds number of 44×10^6 from 0.0046 to 0.0079 at a section lift coefficient of 0.3 and from 0.0053 to 0.0086 at a section lift coefficient of 0.7. For a camouflage painted surface unimproved after painting, increased care taken in the application of the paint resulted in an increase in the maximum Reynolds number at which low drag coefficients were obtainable. This maximum Reynolds number did not exceed 22×10^6 for any of the surface conditions tested unless the surfaces were lightly sanded after painting. In order to approach the drag characteristics of the aerodynamically smooth airfoil section at high-speed and cruising lift coefficients and flight Reynolds numbers, it was necessary to sand the airfoil surfaces lightly after painting.

INTRODUCTION

Application of camouflage paint to airplane wings has been found to decrease the smoothness of the surface of the wing with a resultant increase in the drag of the airfoil. It was believed that the care taken in the preparation and application of the paint was the predominant influence upon the resultant drag characteristics

rather than the inherent qualities of the paint. A preliminary investigation was therefore made in the NACA two-dimensional low-turbulence pressure tunnel to determine the effects on the drag characteristics of various camouflage painting procedures and of two types of camouflage paint. The model tested was of 60-inch chord and had an NACA $65_{(421)}$-420, a = 1.0 airfoil section. Tests were made over an approximate range of section lift coefficient from -0.45 to 0.90 at approximate Reynolds numbers from 6×10^6 to 63×10^6.

DESCRIPTION OF MODEL AND PAINTING PROCEDURES

The model, of 60-inch chord, was constructed of metal in the shops at the Langley Memorial Aeronautical Laboratory and had an NACA $65_{(421)}$-420, a = 1.0 airfoil section. The metal skin was made in one piece from 50.8 percent of the chord on the lower surface around the leading edge to 50.8 percent of the chord on the upper surface. This construction eliminated skin joints and rivets in the region of laminar flow forward of the point of minimum pressure, which is located at 50 percent of the chord. The model was first painted with lacquer primer surfacer, sanded to an aerodynamically smooth finish, and tested to obtain section drag coefficients as a basis for comparison of the camouflage paints. Lacquer camouflage paint was then sprayed on the model and tested in an unimproved condition after painting, as was a synthetic-enamel camouflage paint. Both these camouflage finishes were also tested after specks had been removed by two methods described hereinafter. The painting procedures used on the model for each condition are as follows:

Procedure 1.- Painted with lacquer primer surfacer, glazed locally with pyroxylin putty where needed, and sanded to obtain an aerodynamically smooth surface.

Procedure 2.- Painted with Berry Brothers lacquer, cellulose nitrate, camouflage, No. 43 neutral gray.

(1) Paint stirred thoroughly

(2) Paint strained through fine cheesecloth

(3) Paint thinned with lacquer thinner in ratio of 2 parts thinner to 1 part paint

(4) Model sanded clean

(5) Model sprayed with double coat of paint using chordwise strokes of spray gun for last coat

(6) Model sprayed with single coat of lacquer thinner using chordwise strokes of spray gun

Procedure 3.- Painted with lacquer camouflage paint, olive drab, shade 41, U. S. Army specification 14105 on upper surface and neutral gray, shade 42, U. S. Army specification 14105 on lower surface. Paint applied at U. S. Army Sub-Depot at Langley Field according to a field procedure used there on service airplanes.

(1) Paint stirred

(2) Paint thinned with lacquer thinner in ratio of 1 part thinner to 1 part paint

(3) Model washed with lacquer thinner and wiped with cloth

(4) Model sprayed with double coat of paint

Procedure 4.- Painted with synthetic-enamel camouflage paint, DuPont camouflage 71-009, dark earth.

(1) Paint stirred thoroughly

(2) Paint strained through fine cheesecloth

(3) Paint thinned with synthetic-enamel thinner (Sherwin-Williams Aerotol) in ratio of 3 parts paint to 1 part thinner

(4) Model sanded clean

(5) Model sprayed with double coat of paint using chordwise strokes of spray gun for last coat

(6) Model sprayed with single coat of synthetic-enamel thinner using chordwise strokes of spray gun

Procedure 5.- Painted with synthetic-enamel camouflage paint, DuPont camouflage 71-009, dark earth.

(1) Paint stirred thoroughly

(2) Paint strained through coarse cheesecloth

(3) Paint thinned with synthetic-enamel thinner (Sherwin-Williams Aerotol) in ratio of 3 parts paint to 1 part thinner

(4) Model sanded clean

(5) Model sprayed with double coat of paint using chordwise strokes of spray gun for last coat

After the model sprayed with lacquer camouflage paint according to procedure 2 was tested, the surface was sanded lightly by hand in a chordwise direction with No. 320 carborundum paper to remove all specks. After the model sprayed with synthetic-enamel camouflage paint according to procedure 4 was tested, the specks were cut off with a steel blade pushed lightly across the surface at the locations of the specks. With the exception of painting procedure 1 for the aerodynamically smooth airfoil, neither the sanding process after painting nor the removal of specks with a steel blade is included in the term "painting procedure" used herein.

TEST METHODS

The tests were made in the NACA two-dimensional low-turbulence pressure tunnel. The section drag coefficients were obtained by the wake-survey method, in which an integrating manometer was used. A manometer arrangement, which integrated the lift reaction of the model on the floor and ceiling of the tunnel test section, was used to obtain the section lift coefficients. Details of test methods are given in reference 1.

RESULTS AND DISCUSSION

The drag data obtained are presented in figures 1 to 6 as variation of section drag coefficient c_d with Reynolds number R and in figures 7 to 12 as variation of section drag coefficient c_d with section lift coefficient c_l at four Reynolds numbers. The polars at these four Reynolds numbers are replotted in figure 13 to facilitate comparison of the results for the six surface finishes tested. The section drag coefficients obtained with the aerodynamically smooth surface (painting procedure 1, figs. 1 and 7) serve as a basis for comparison and are referred to as "basic drag coefficients."

When the airfoil was sprayed with lacquer camouflage paint according to procedure 2, the section drag coefficients at a section angle of attack of 0° showed no appreciable increase over the basic drag coefficients for Reynolds numbers less than 20×10^6 (fig. 2). The section drag coefficients outside the low-drag range were slightly higher, however, than the basic drag coefficients (fig. 13). At Reynolds numbers higher than 20×10^6, the section drag coefficient increased considerably from a basic section drag coefficient of 0.0044 to approximately 0.0078 at a section angle of attack of 0° (figs. 1 and 2). The surface was then sanded lightly with No. 320 carborundum paper to remove dust, lint, or paint specks. When the specks were removed, the section drag coefficients were slightly reduced at Reynolds numbers less than 14×10^6 (fig. 3) and were reduced from 0.0078 (fig. 2) to 0.0060 (fig. 3) at the higher test Reynolds numbers. The inconsistency of the sharp increase in drag with Reynolds number as the pressure of the tunnel air (referred to as "tank pressure") was increased led to an examination of the model, which disclosed scratches in the surface probably caused by the previous sanding. Although the reason for this inconsistency with increase in tank pressure is not definitely understood, it is possible that dust and oil vapor introduced into the air stream by the air compressors may have accumulated in the scratches with a resultant increase in roughness. The model therefore was resanded with No. 400 carborundum paper, which is lighter than No. 320, to avoid sanding through the already thin layer of camouflage paint. Although the intensity of light reflected from the airfoil surface after the second sanding was slightly greater than for the unsanded condition, the sanded surface could still be considered nonspecular. Removal of the scratches reduced the

section drag coefficients at a section angle of attack of 0° to values that are approximately equal to the values of the aerodynamically smooth airfoil up to the highest test Reynolds number, which was 52×10^6. The section drag coefficients were, however, still slightly higher than for the aerodynamically smooth airfoil outside the low-drag range (fig. 13).

When the airfoil was sprayed with lacquer camouflage paint at the U. S. Army Sub-Depot at Langley Field (procedure 3), the section drag coefficients were higher than for the aerodynamically smooth airfoil throughout the entire range of test Reynolds number. (Compare fig. 4 with fig. 1.) When the model was sprayed with a similar paint at LMAL (procedure 2), section drag coefficients approximately as low as for the aerodynamically smooth airfoil were obtained up to a Reynolds number of 20×10^6. At the higher test Reynolds numbers, the difference between the drag values for procedures 2 and 3 was relatively small. The model surface, when painted at the Army Sub-Depot, contained a larger number of specks than when painted at LMAL, and specks have been shown by these tests to be the cause of large increases in the section drag coefficient. It is believed that the Army painting procedure could be improved by including the use of paint strainers and a final spraying of lacquer thinner over the surface, since the omission of these steps was the main difference between the painting procedures of the Army and LMAL and since both visual observation and touch indicated that the surface sprayed with a final coat of thinner was smoother.

Adverse effects of specks were also evident when the model was painted with synthetic-enamel camouflage (figs. 5, 6, and 13). Figure 5 gives the drag results of the model painted with synthetic-enamel camouflage with no coat of thinner applied and with the paint strained through coarse rather than fine cheesecloth (painting procedure 5). Figure 6 gives the drag results of the model sprayed with synthetic-enamel camouflage (painting procedure 4) after the specks had been cut off with a steel blade. The model, which was not sanded after removal of the specks, gave lower drag values up to a Reynolds number of 41×10^6 than the model sprayed with synthetic enamel with no specks removed. A comparison of the polars presented in figure 13 also shows this result.

An adverse effect on section lift coefficient of specks on both the unimproved lacquer and synthetic-enamel camouflaged surfaces may be noted in figures 1 to 6. A section lift coefficient of 0.32 was obtained at a section angle of attack of 0° for all surface conditions with specks removed (figs. 1, 3, and 6), whereas a reduction in section lift coefficient to values of 0.29 and 0.30 resulted when specks were present on the surface (figs. 2, 4, and 5).

The painting procedures used for these tests were not sufficiently controlled or varied systematically enough to permit drawing very many definite conclusions as to the quantitative effects of individual steps in the procedures. The data are indicative, however, of the drag results likely to be obtained on a low-drag airfoil with camouflage painting procedures such as those used. The results also show that the care taken throughout the painting procedure to reduce the number and size of specks on the airfoil surface and to prevent an "orange-peel" effect in the paint has an important effect on the resultant values of the section drag coefficient.

Most of the paint and lint specks in the finishes were introduced during the preparation of the paint and in the cleaning of the surface before painting. A large number of these specks can be eliminated by straining the paint before spraying and by cleaning the surface before spraying by means other than washing with a paint thinner. The surface painted by procedure 3 contained a large number of lint specks that were introduced when the model was washed with lacquer thinner and wiped with a cloth. The use of a lacquer thinner to clean a lacquer-base paint is considered inadvisable since the paint is softened by the thinner so that lint and dust may stick to the surface.

An orange-peel effect in the paint finish may be reduced to a large extent by skill in applying the paint. This skill includes a knowledge of the correct distance to hold the spray gun from the surface and the pressure in the gun necessary to obtain a finish that dries uniformly and not too rapidly. It is also of importance to spray the paint evenly over the surface without thin or thick layers or running of the paint. Although the benefits derived from the final coat of thinner are not clearly indicated by these tests, it is felt that

the thinner helps reduce the orange-peel effect since both visual observation and touch indicated that the surface which had been sprayed with a coat of thinner was smoother. The addition of this coat of thinner increases the drying time of the outer layer of paint and permits the under layer to spread out over the surface more smoothly without the orange-peel effect that might occur as a result of too-rapid external drying.

Since the painting procedures used for the lacquer and synthetic-enamel camouflage paints were not the same, no definite conclusions may be drawn as to any possible differences in results attributable to each type of paint. Regardless of the type of paint used, the maximum Reynolds number at which the section drag coefficients of the aerodynamically smooth airfoil are approached varies directly with the care with which the paint is prepared and sprayed on the airfoil and the method of cleaning the airfoil surface before painting. For the model unimproved in any way after painting, this conclusion is clearly indicated in table I. It should be noted, however, that the maximum Reynolds number at which relatively low values of section drag coefficient were obtained in no case exceeded 22×10^6 unless the airfoil surfaces were lightly sanded after painting. Table I also presents values of the section drag coefficient for all surface conditions tested at high-speed and cruising lift coefficients and flight Reynolds numbers. Section drag coefficients approaching those of the aerodynamically smooth airfoil were obtained at Reynolds numbers greater than 22×10^6 only when the airfoil surfaces were lightly sanded after painting.

CONCLUSIONS

The results of an investigation of the effects of camouflage paints and painting procedures upon the drag characteristics of an originally smooth and fair low-drag airfoil indicated the following conclusions:

1. The effect of a typical field application of camouflage paint unimproved after painting may be shown in the following drag data at a Reynolds number of 44×10^6:

Surface condition	Section drag coefficient at a section lift coefficient of	
	0.3	0.7
Typical field application of camouflage paint	0.0079	0.0086
Aerodynamically smooth	.0046	.0053

2. For a camouflage painted surface unimproved after painting, increased care taken in the application of the paint resulted in an increase in the maximum Reynolds number at which low drag coefficients were obtainable. In no case, however, did this maximum Reynolds number (22×10^6) extend into the flight range for large airplanes for which the section tested would normally be used. The decrease in drag coefficient resulting from improved painting procedures became less significant, moreover, as the Reynolds number and lift coefficient were increased to cruising values for large heavily loaded airplanes.

3. In order to approach the drag characteristics of the smooth and fair airfoil section at flight Reynolds numbers, it was necessary to sand the airfoil surfaces lightly after painting.

Langley Memorial Aeronautical Laboratory
National Advisory Committee for Aeronautics
Langley Field, Va.

REFERENCE

1. Jacobs, Eastman N., Abbott, Ira H., and Davidson, Milton: Preliminary Low-Drag-Airfoil and Flap Data from Tests at Large Reynolds Numbers and Low Turbulence, and Supplement. NACA ACR, March 1942.

TABLE I.- EFFECT OF PAINTING PROCEDURE ON REYNOLDS NUMBER AND DRAG CHARACTERISTICS

CONFIDENTIAL

Painting procedure	Description of surface condition	Maximum Reynolds number at which relatively low values of section drag coefficient were obtained	c_d at $R = 25 \times 10^6$ (approx.)		c_d at $R = 44 \times 10^6$ (approx.)	
			$c_l = 0.3$	$c_l = 0.7$	$c_l = 0.3$	$c_l = 0.7$
3	Typical field application of lacquer camouflage paint; unimproved after painting	Less than 4×10^6	0.0083	0.0095	0.0079	0.0086
2	Careful application of lacquer camouflage paint with final coat of thinner; unimproved after painting	20×10^6	0.0067	0.0083	0.0078	0.0088
4	Careful application of synthetic-enamel camouflage paint with final coat of thinner; specks cut off after painting	22×10^6	0.0048	0.0075	0.0070	0.0083
5	Careful application of synthetic-enamel camouflage paint; no final coat of thinner; unimproved after painting	Less than 6×10^6	0.0065	0.0079	0.0066	0.0083
2	Airfoil surfaces lightly sanded after painting	Greater than 52×10^6	0.0042	0.0053	0.0045	0.0062
1	Aerodynamically smooth finish	Greater than 60×10^6	0.0041	0.0049	0.0046	0.0053

CONFIDENTIAL

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

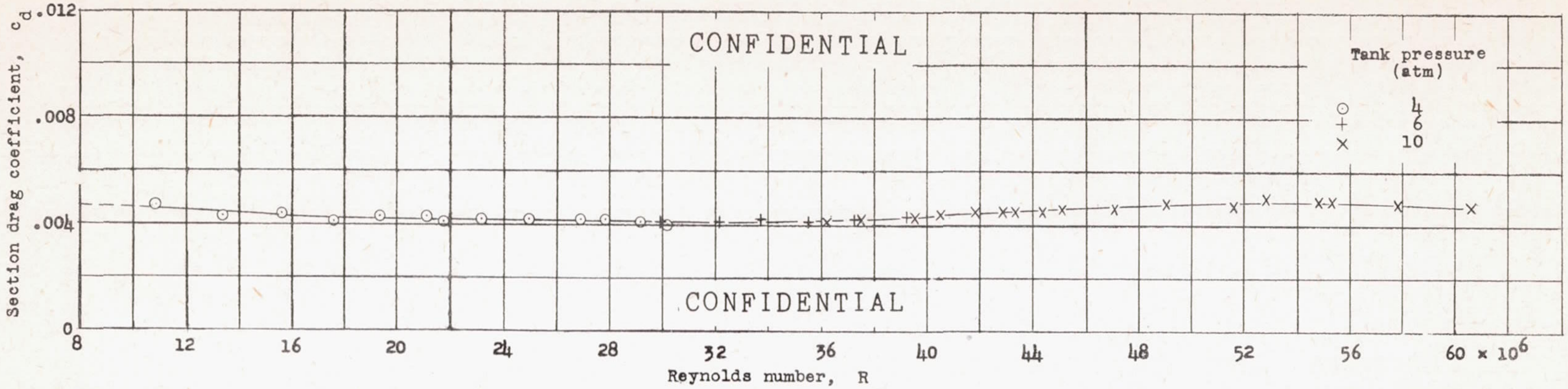


Figure 1 .- Variation of section drag coefficient with Reynolds number for 60-inch-chord NACA $65_{(421)}$-420, a = 1.0 airfoil section; section angle of attack, 0°; c_l, 0.32; smooth condition: painting procedure number 1. Test, TDT 328.

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS.

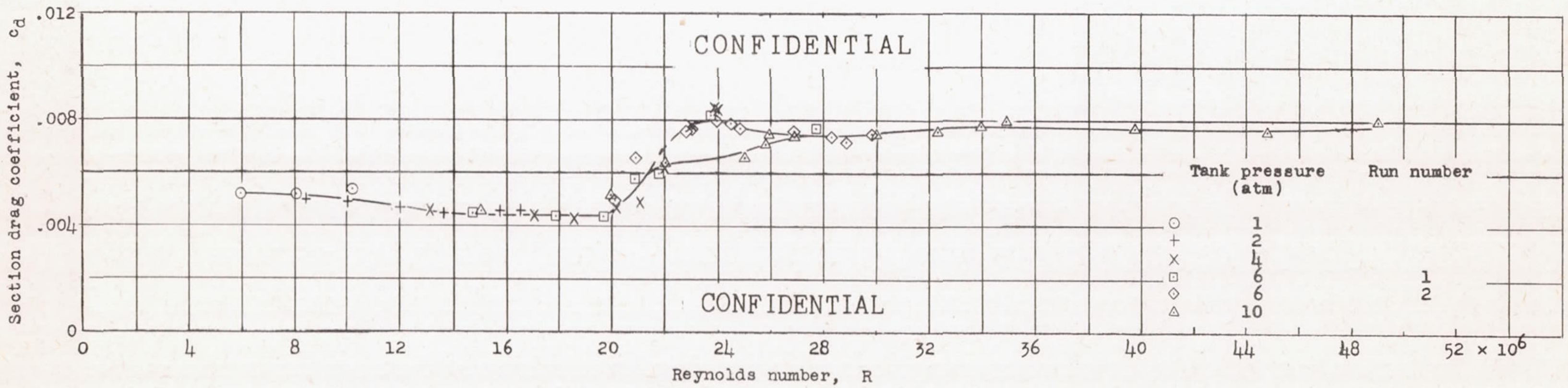


Figure 2 .- Variation of section drag coefficient with Reynolds number for 60-inch-chord NACA $65_{(421)}$-420, a = 1.0 airfoil section; section angle of attack, 0°; c_l, 0.29; lacquer camouflage unimproved after painting; painting procedure number 2. Test, TDT 461.

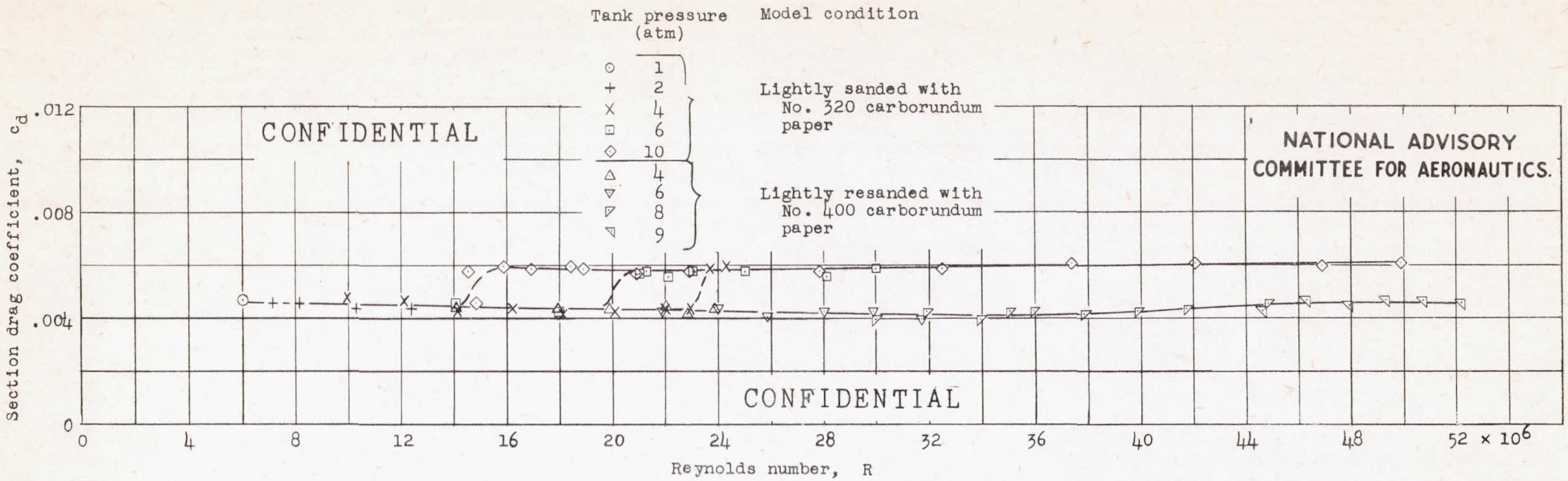


Figure 3 .- Variation of section drag coefficient with Reynolds number for 60-inch-chord NACA $65_{(421)}$-420, a = 1.0 airfoil section; section angle of attack, 0°; c_l, 0.32; lacquer camouflage lightly sanded; painting procedure number 2. Test, TDT 461.

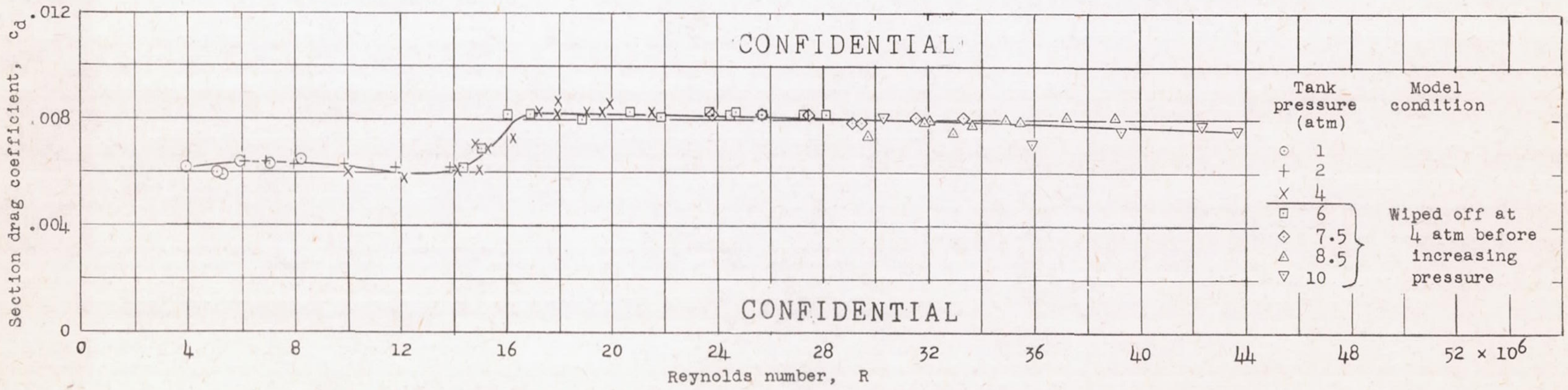


Figure 4 .- Variation of section drag coefficient with Reynolds number for 60-inch-chord NACA $65_{(421)}$-420, a = 1.0 airfoil section; section angle of attack, 0°; c_l, 0.30; lacquer camouflage applied by U. S. Army unimproved after painting; painting procedure number 3. Test, TDT 515.

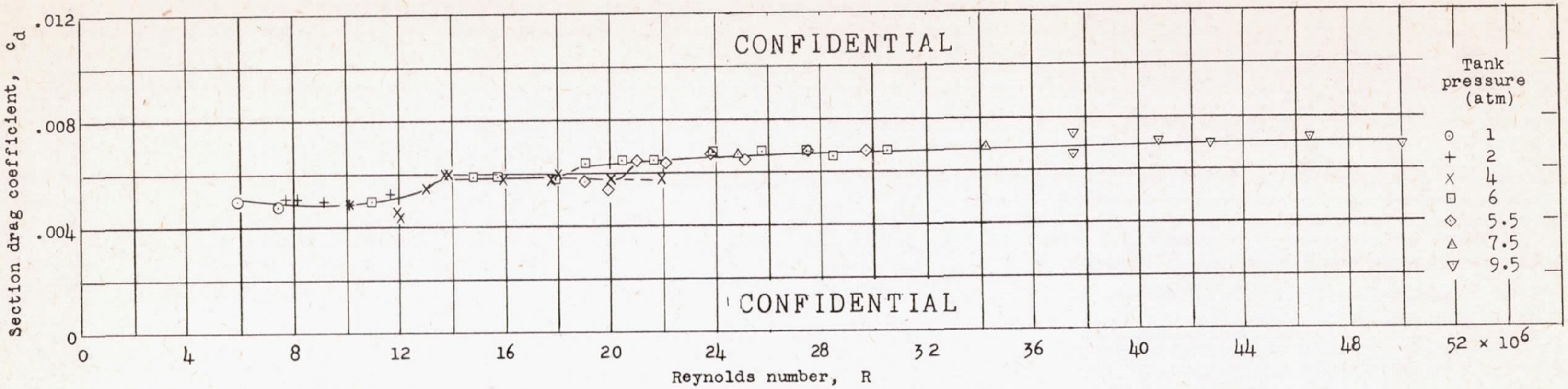


Figure 5 .- Variation of section drag coefficient with Reynolds number for 60-inch-chord NACA 65(421)-420, a = 1.0 airfoil section; section angle of attack, 0°; c_l, 0.30; synthetic-enamel camouflage unimproved after painting; painting procedure number 5. Test, TDT 499.

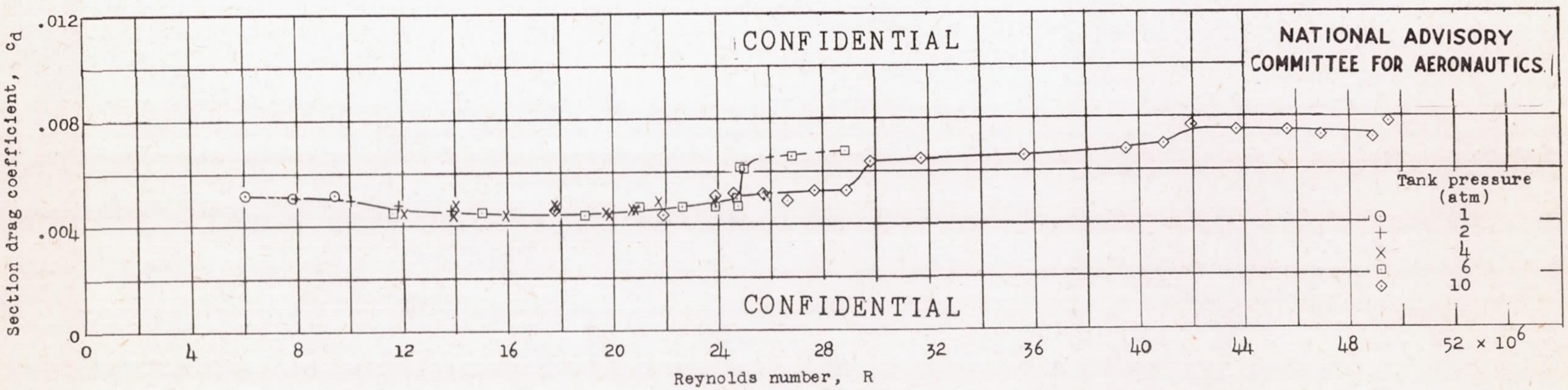


Figure 6 .- Variation of section drag coefficient with Reynolds number for 60-inch-chord NACA 65(421)-420, a = 1.0 airfoil section; section angle of attack, 0°; c_l, 0.32; synthetic-enamel camouflage with all specks cut off with blade; painting procedure number 4. Test, TDT 486.

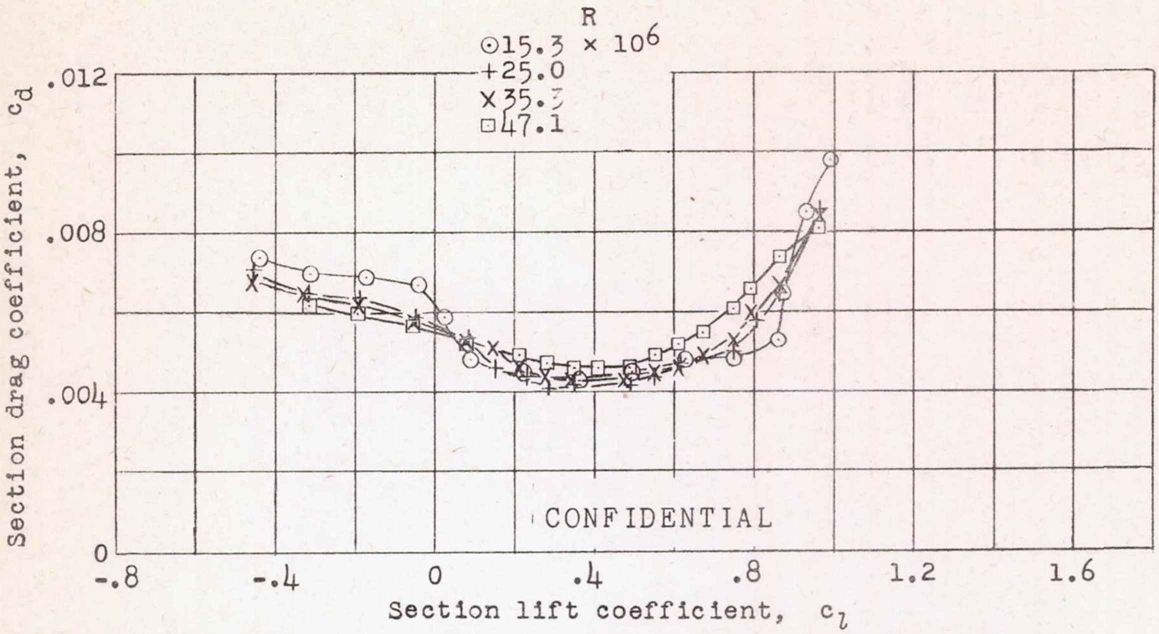


Figure 7 .- Variation of section drag coefficient with section lift coefficient for 60-inch-chord NACA $65_{(421)}$-420, a = 1.0 airfoil section; smooth condition; painting procedure number 1. Test, TDT 328.

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

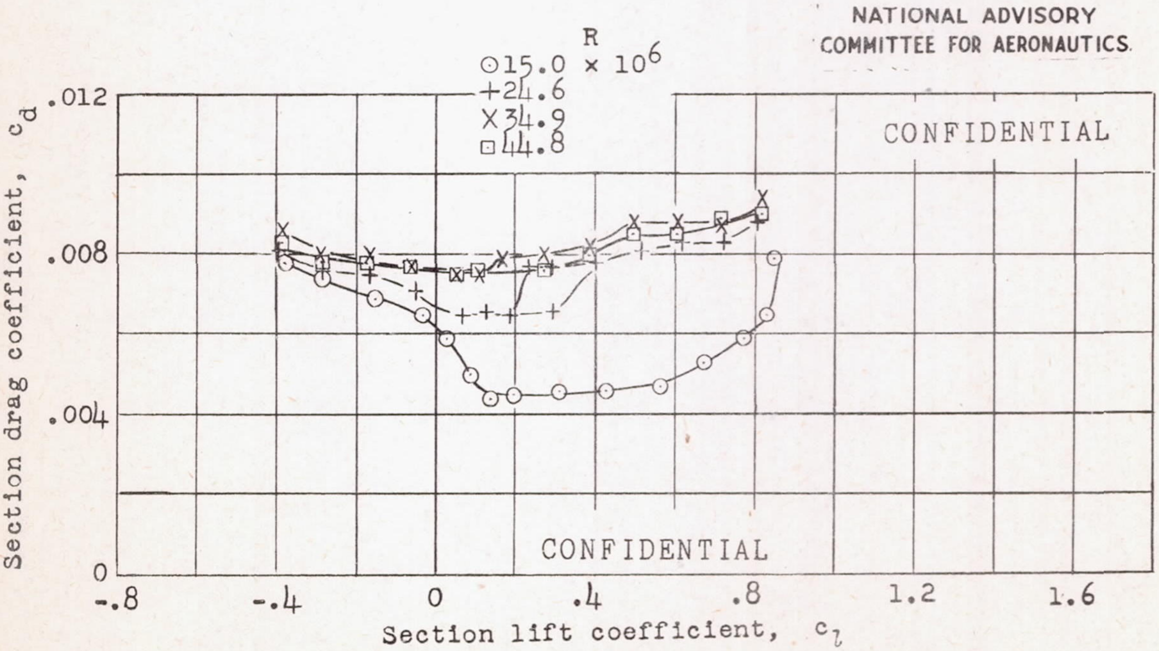


Figure 8 .- Variation of section drag coefficient with section lift coefficient for 60-inch-chord NACA $65_{(421)}$-420, a = 1.0 airfoil section; lacquer camouflage unimproved after painting; painting procedure number 2. Test, TDT 461.

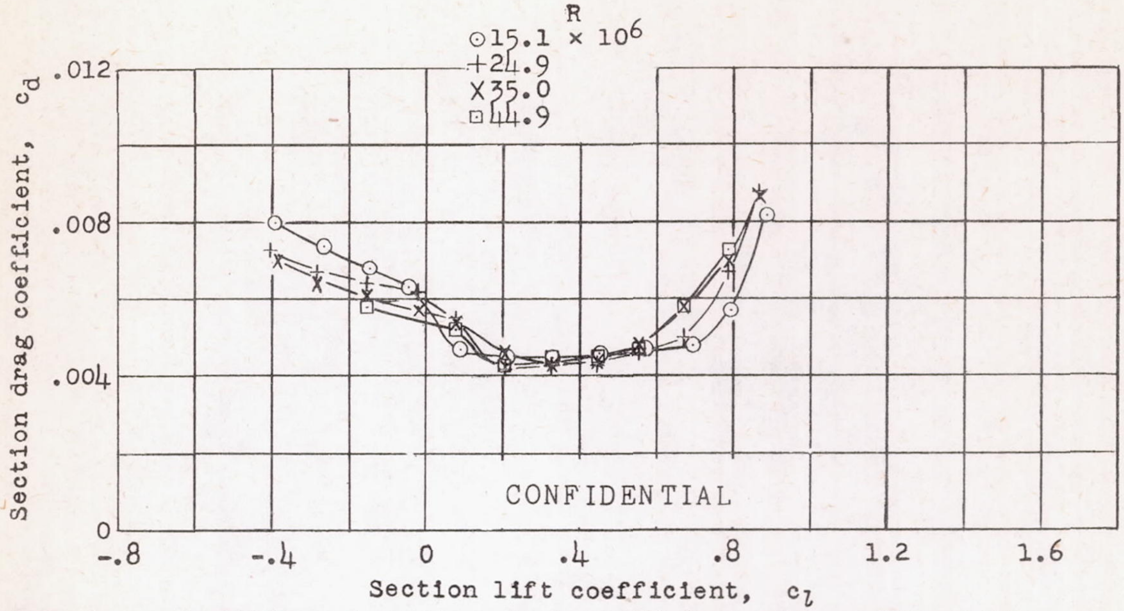


Figure 9 .- Variation of section drag coefficient with section lift coefficient for 60-inch-chord NACA $65_{(421)}$-420, a = 1.0 airfoil section; lacquer camouflage lightly sanded; painting procedure number 2. Test, TDT 461.

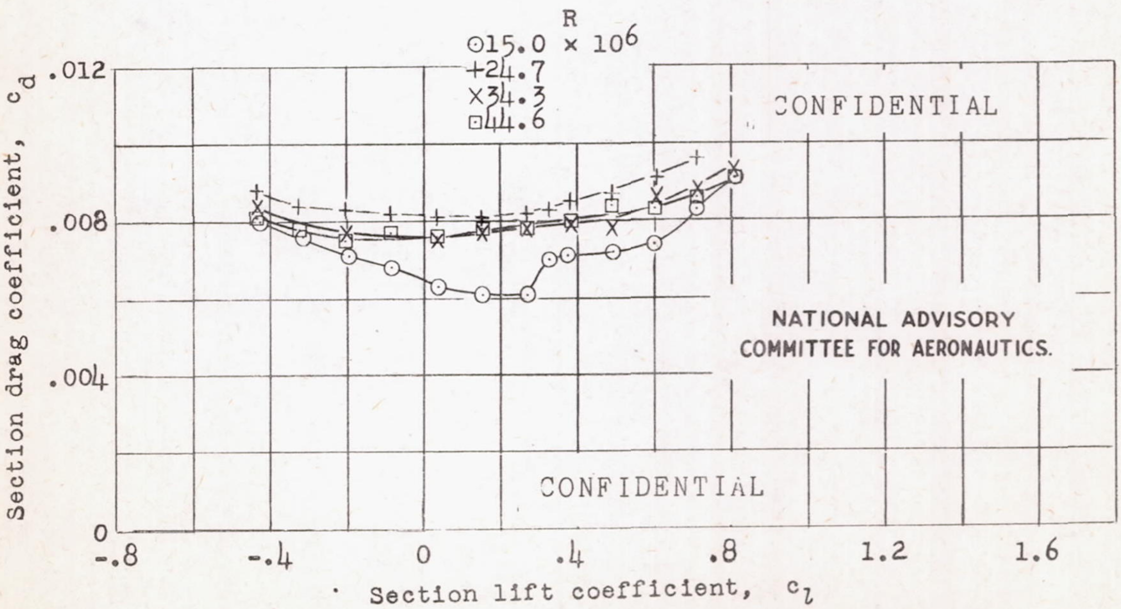


Figure 10 .- Variation of section drag coefficient with section lift coefficient for 60-inch-chord NACA $65_{(421)}$-420, a = 1.0 airfoil section; lacquer camouflage applied by U. S. Army unimproved after painting; painting procedure number 3. Test, TDT 515.

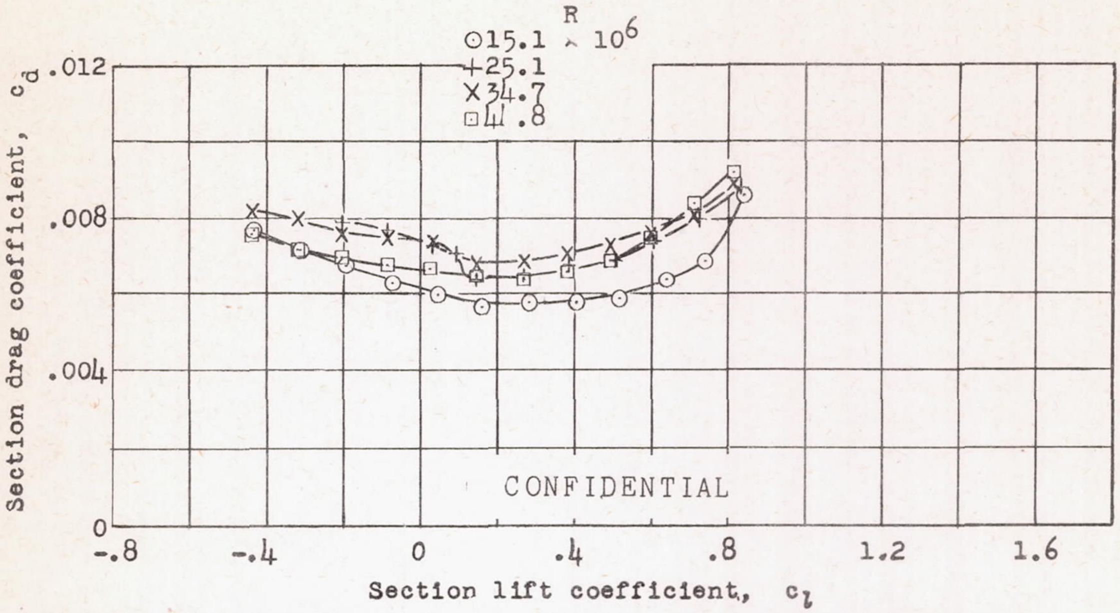


Figure 11 .- Variation of section drag coefficient with section lift coefficient for 60-inch-chord NACA $65_{(421)}$-420, a = 1.0 airfoil section; synthetic-enamel camouflage unimproved after painting; painting procedure number 5. Test, TDT 499.

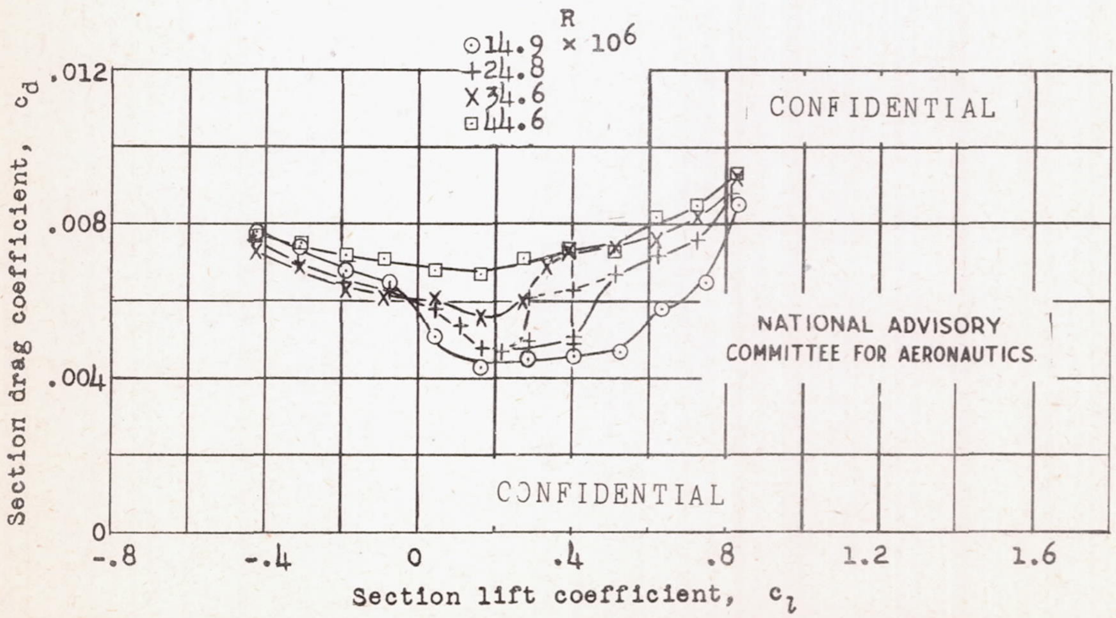
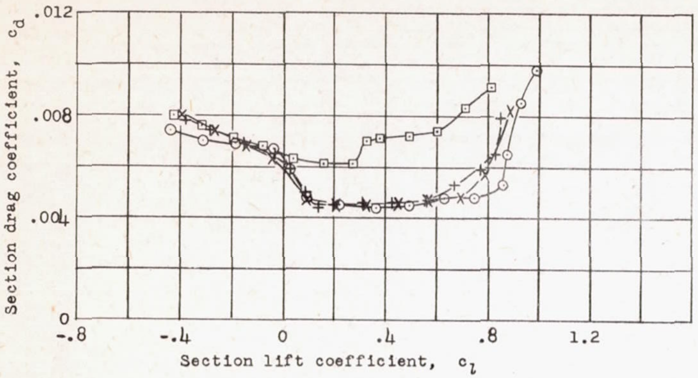


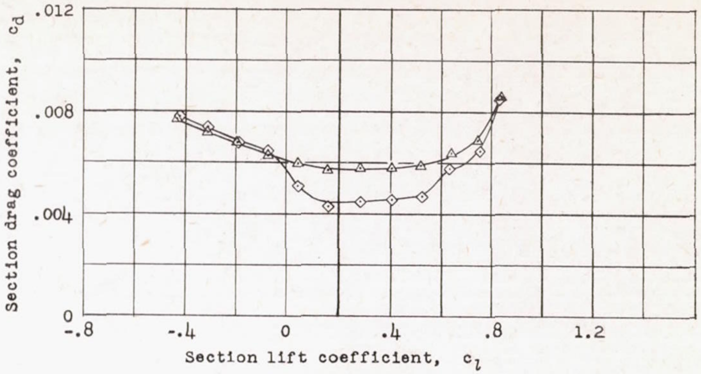
Figure 12 .- Variation of section drag coefficient with section lift coefficient for 60-inch-chord NACA $65_{(421)}$-420, a = 1.0 airfoil section; synthetic-enamel camouflage with all specks cut off with blade; painting procedure number 4. Test, TDT 486.

CONFIDENTIAL

	Paint	Surface condition	Procedure
⊙	Lacquer primer surface	Aerodynamically smooth	1
+	Lacquer camouflage	Unimproved; painted by LMAL	2
×	Lacquer camouflage	Lightly sanded	2
⊡	Lacquer camouflage	Unimproved; painted by Army	3



	Paint	Surface condition	Procedure
◇	Synthetic-enamel camouflage	All specks cut off	4
△	Synthetic-enamel camouflage	Unimproved	5

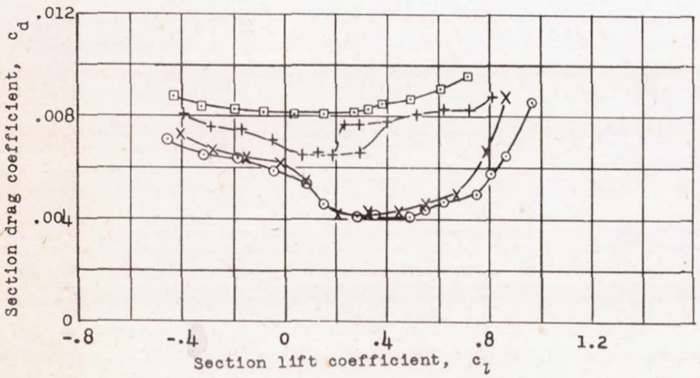


(a) R, 15×10^6 (approx.).

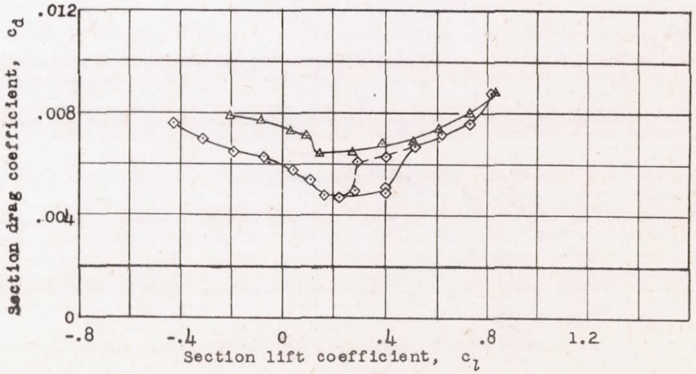
CONFIDENTIAL

CONFIDENTIAL

	Paint	Surface condition	Procedure
⊙	Lacquer primer surface	Aerodynamically smooth	1
+	Lacquer camouflage	Unimproved; painted by LMAL	2
×	Lacquer camouflage	Lightly sanded	2
⊡	Lacquer camouflage	Unimproved; painted by Army	3



	Paint	Surface condition	Procedure
◇	Synthetic-enamel camouflage	All specks cut off	4
△	Synthetic-enamel camouflage	Unimproved	5



(b) R, 25×10^6 (approx.).

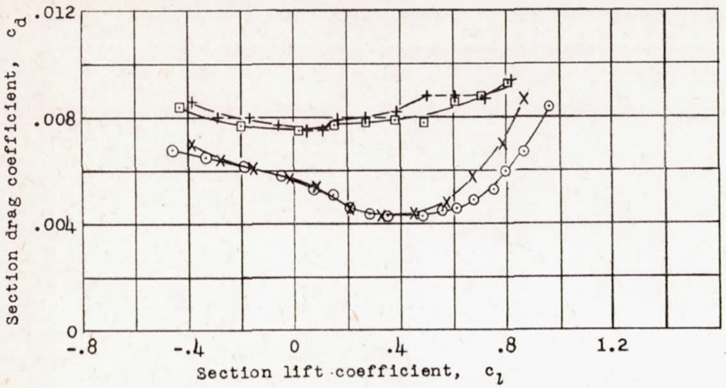
Figure 13.- Comparison of drag characteristics of 60-inch-chord NACA $65_{(421)}$-420, a = 1.0 airfoil section with six surface conditions.

CONFIDENTIAL

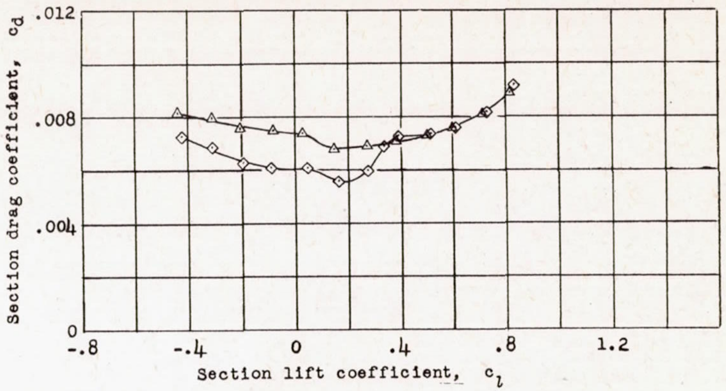
NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS.

CONFIDENTIAL

	Paint	Surface condition	Procedure
⊙	Lacquer primer surface	Aerodynamically smooth	1
+	Lacquer camouflage	Unimproved; painted by LMAL	2
×	Lacquer camouflage	Lightly sanded	2
⊡	Lacquer camouflage	Unimproved; painted by Army	3



	Paint	Surface condition	Procedure
◇	Synthetic-enamel camouflage	All specks cut off	4
△	Synthetic-enamel camouflage	Unimproved	5

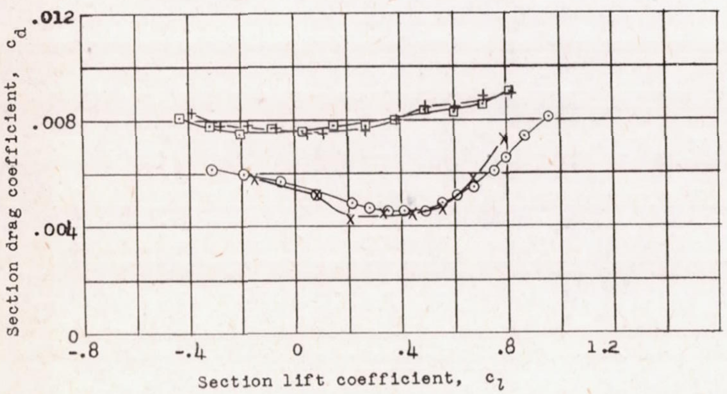


CONFIDENTIAL

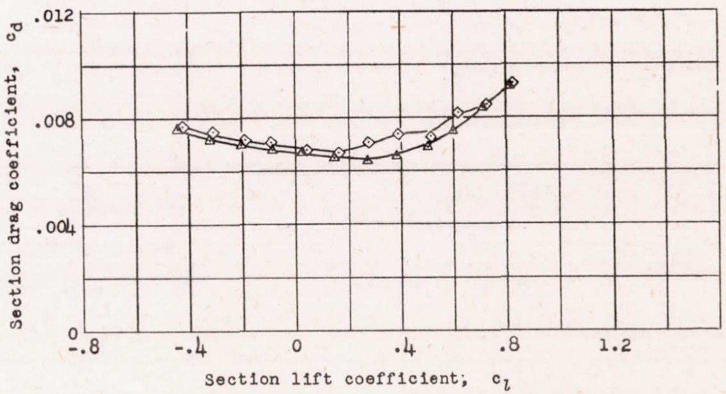
(c) R, 35×10^6 (approx.).

CONFIDENTIAL

	Paint	Surface condition	Procedure
⊙	Lacquer primer surface	Aerodynamically smooth	1
+	Lacquer camouflage	Unimproved; painted by LMAL	2
×	Lacquer camouflage	Lightly sanded	2
⊡	Lacquer camouflage	Unimproved; painted by Army	3



	Paint	Surface condition	Procedure
◇	Synthetic-enamel camouflage	All specks cut off	4
△	Synthetic-enamel camouflage	Unimproved	5



(d) R, 45×10^6 (approx.).

CONFIDENTIAL

Figure 13.- Concluded.

NATIONAL ADVISORY
COMMITTEE FOR AERONAUTICS